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A method for studying the respiration and decomposition of litter

INTRODUCTION.

The rate of decomposition of plant litter is important for a number of reasons. For example, in woodlands the greatest loss of organic matter from the ecosystem results from loss as carbon dioxide and leachates derived from decomposition, and in managed woodlands this far exceeds the loss by harvesting (Ovington 1962).

Various investigators (Bocock and Gilbert 1957, Bocock *et al.* 1960, Bocock 1964, Shanks and Olson 1961) have found that the rate of loss in weight of tree leaves placed on the ground in nylon net bags depends on the tree species, the chemical composition of the leaves, soil conditions, moisture, and temperature. However, where nylon mesh bags are used loss in weight is not necessarily caused by decomposition. It may be due to the removal of whole leaves or parts of leaves, for example by being pulled into the burrows of the larger earthworms, unless the mesh is so fine as to prevent the physical removal of leaves or leaf fragments. Only a part of the loss in weight in such observations may be from decomposition, partly in the animal gut and partly by free-living micro-organisms.

Another method for studying loss in weight of plant litter is to label the material in some way and place it in or on the soil, to be recovered and examined later. This technique has been used by Frankland (1966) for studying decomposition of bracken petioles marked with plastic labels and placed on the ground. Hayes (1965 a, b) studied the decomposition of coniferous leaf litter by attaching each needle to a length of nylon thread, some of the needles being placed on the soil surface and some

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buried. He also used the hair net technique and found some evidence that *Picea sitchensis* needles disappeared rather more slowly from hair nets than when exposed on thread. Heal *(pers. comm.)* has observed this effect with elm litter. Litter can also be marked with radio-isotopes for following the rate of disappearance (Murphy 1962).

However, the above methods all measure the *disappearance* of litter from the original sample, and disappearance does not necessarily mean decomposition for the reasons outlined above (Cf. Wiegert and Evans 1964). On the other hand, laboratory measurements of the rate of litter decomposition have often involved such artificial methods as to have little relevance to field conditions. Indeed, Daubenmire and Prusso (1963) concluded that a rating of plant species according to the decomposibility of their litter based on experiments done in an artificial environment is largely an artifact determined by, among other things, the temperature chosen for the experiment.

The method described below, which uses glass tubes containing soil and litter, is an attempt to make accurate measurements on litter decomposition under any chosen set of environmental conditions. Using this method respiration can be measured repeatedly on the same tubes for a year or more, and replicate tubes can be removed at intervals, their respiration measured, and the litter can be removed for chemical and biological analysis. These tubes also have the advantage that much more control can be exerted over the conditions of decomposition, and physical loss of material from the tubes other than by decomposition does not occur. By comparing the results of such experiments with field observations, useful information on litter decomposition can be obtained.

NEW METHOD

In a preliminary trial of this method, litter was collected in October 1964 from Meathop Wood (oak-ash wood on limestone), Bogle Crag Wood (oak wood on slate), and Roudsea Wood National Nature Reserve (alder on alluvium). The litter was sorted and cleaned with a soft brush, and was air-dried for 24 hours. Samples of the litter were removed for analysis. Soil was obtained from Meathop Wood (mull, 0-10 cm depth, pH 4.85) and Bogle Crag Wood (mor, H-layer was collected, pH 3.7). It was passed through a 5 mm sieve and all fragments of plant and animal material were removed by hand. Approximately equal weights of soil were placed

in each tube. The glass tubes used were 28 mm diameter and 15 cm long, one end being closed by a plug of glass wool. The litter was cut into fragments 1 cm x 1 cm, and approximately equal weights of litter were placed in each tube. In the tubes containing mull soil the litter was mixed with the soil, while in the tubes of H-layer material the litter was placed on the soil surface.

The tubes were placed upright in a box in the field, exposed to ordinary seasonal temperature changes but protected from rain by a roof. Litter and soil were kept moist by watering as necessary until the excess drained out of the tube (this normally required 5 ml every 2 weeks or so). Weekly maximum and minimum temperatures were noted.

At intervals all the experimental tubes were removed to a cool room (ca. 12°C) and some of the tubes were taken for measurement of oxygen uptake, after which all the tubes were returned to the field. For measurement of oxygen uptake a manometric method is preferred. Methods involving electrolytic generation of oxygen and electrical recording of oxygen uptake are fraught with practical difficulties, and much time can be spent correcting faults in such equipment.

For the manometric measurement of oxygen uptake a Dixon manometer (D i x o n 1952, p. 6) is used in conjunction with a flask of the type described by P a r k i n s o n and C o u p s (1963). The base of the flask consists of a "Quickfit" B40 cone with a flat base sealed on 15 cm from the ground end. The experimental tube is placed in this base, in the bottom of which is 5 mm or so of water which keeps the air in the flask saturated with water vapour and also seals the base of the glass tube. Thus, gas exchange takes place from the top of the tube only. N. sodium hydroxide (for absorption of carbon dioxide) is introduced into the annular well via a B10/19 neck, and the flask is connected to a Dixon manometer by a B14/23 joint. The Dixon manometer has several advantages, e.g., it is a direct reading instrument and so calculations involving flask constants are not required. This not only saves time in setting up (matched components are unnecessary) but also means that the apparatus can be used easily over a range of temperatures. Furthermore, the apparatus is independent of fluctuations in atmospheric pressure during the course of the respiration measurements.

The respirometer water bath temperature is important, many workers have used unrealistic temperatures (25 to 30°C) when working with soils from temperate and cool climates. In the present experiment, oxygen uptake was measured at 10 °C over a period of eight hours (after a minimum of 16 hours in the water bath to equilibrate) and the respiration

rate was calculated from the straight line of oxygen uptake against time. At the end of the experiment the contents of the tubes were removed and remaining fragments of leaves were collected, dried at 105°C and weighed. They were then ignited to constant weight at 550°C and the loss in weight of organic matter during the experimental period was calculated.

RESULTS OF A PRELIMINARY STUDY

Oxygen uptake during the 53 weeks of the experiment is shown in Figures 1 (tubes with H-layer material), 2 and 3 (tubes with mull soil). In each case a correction has been applied by subtracting respiration of a control tube containing soil only. Because of the lack of a statistically valid number of replicates (tubes were set up in pairs) only preliminary conclusions can be drawn from the results. However, duplicate results agreed well (cf. Table 3) and the respiration values gave good curves (Figures 1 to 3).

The respiration at week 2 ranged from 27.89 to 50.45 μl 02/h according to species. At week 53 the range was 3.88 to 9.58 μl 02/h. It seems likely that the wide range of values at the beginning of the experiment reflects the content of organic matter readily available to micro-organisms. At the end of the experiment the residual material appears to be much more resistant. In Table 1, respiration at week 2 and at week 53 is given on the
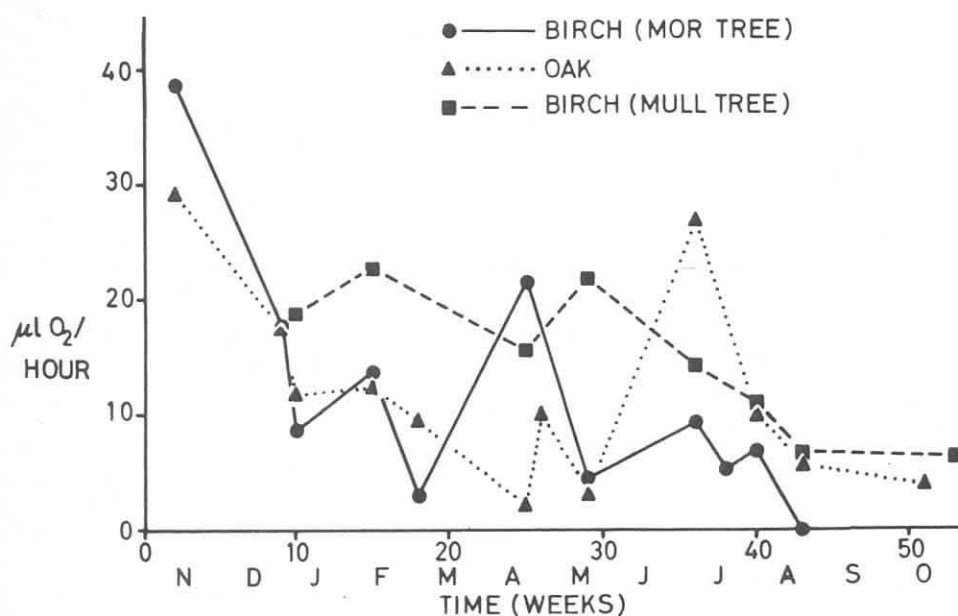

Fig. 1

O$_2$ uptake curves of birch and oak litter with H layer material
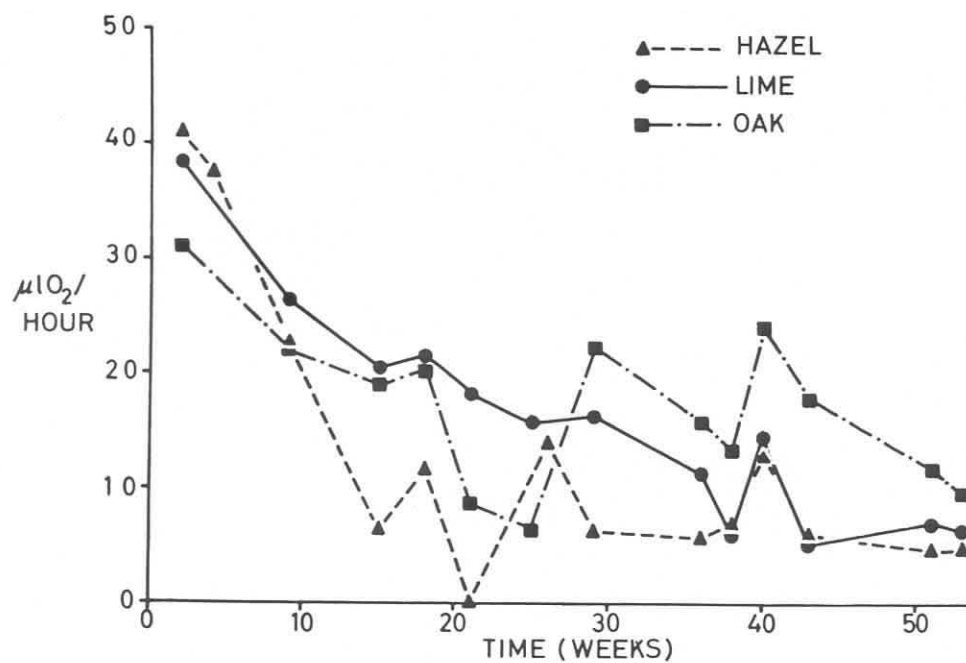
Fig. 2

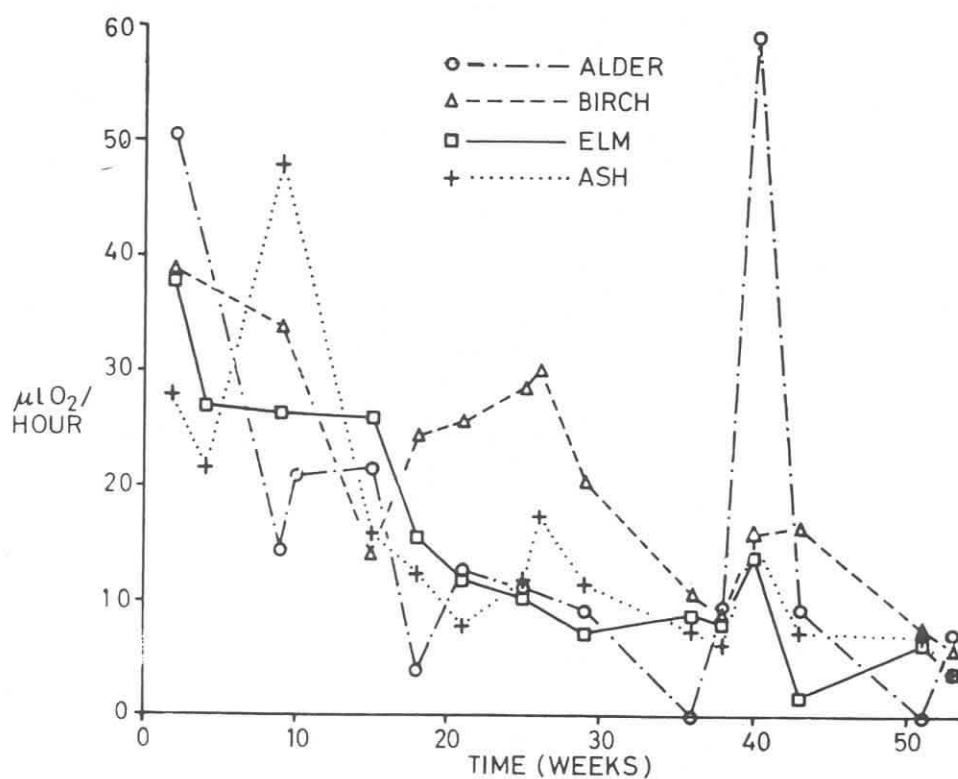O_2 uptake curves of hazel, lime, and oak litter with mull soil

Fig. 3

O_2 uptake curves of alder, birch, elm, and ash litter with mull soil

basis of the organic matter content of the litter. If the respiration at week 53 is expressed as a percentage of that at 2 weeks it shows that, in the mull soil, hazel is about 15 %, alder, ash, birch, and lime are about 27 % and oak is 57 %. This indicates that after 1 year the residue of the hazel litter is in a form relatively unusable by microorganisms, whereas that of oak, possibly because of its lower rate of decomposition, is in a relatively usable state.

Table 1

soil	litter	O2 uptake µl/g organic matter/h week 2	week 53	week 53 as % of week 2
mull	lime M	162.19	46.00	28.36
"	ash M	123.57	34.67	28.06
"	birch M	160.06	41.52	25.94
"	elm M	175.44	N A	N A
"	hazel M	175.40	25.95	14.79
"	oak M	130.71	74.38	56.90
"	alder R	207.19	54.43	26.27
H-layer	birch B	164.20	N A	N A
"	birch B	N A	30.59	N A
"	oak B	126.71	44.54	35.15
"	birch M	N A	40.89	N A

M = Meathop Wood, B = Bogle Crag Wood, R = Roudsea Wood

Table 2   Tubes with mull soil

litter type	organic carbon % OD	measured dry wt loss (ash-free basis) (g)	loss in wt of organic carbon (g)	estimated loss in wt of C as CO_2 (g)
lime	48.8	0.0994	0.0485	0.0765
ash	44.6	0.1138	0.0508	0.0703
birch M	51.4	0.1012	0.0520	0.0944
elm	42.25	–	–	0.0652
hazel	47.05	0.0522	0.0246	0.0520
oak M	48.45	0.1092	0.0529	0.0811
alder	49.35	0.1125	0.0555	0.0689

Table 3
Percentage loss in organic matter of litter after 53 weeks

litter	soil type in tubes		
	mull	H-layer	
birch M	40.87) 41.34 41.80)	35.63) 35.63 -)	
oak M	45.88) 42.36 38.84)	26.57) 27.68 28.78)	
birch B	35.58) 35.58 -)	34.18) 33.71 33.24)	
oak B	48.64) 51.49 54.33)	32.05) 29.72 27.39)	

In most cases there was a pronounced fall in respiration rate during the first 25 weeks, with a slower fall or levelling-out from 25 to 53 weeks. The pronounced peak at week 40 is difficult to explain.

The areas below some of the oxygen uptake curves were measured, and the total volume of oxygen taken up was calculated. From this the total carbon dioxide evolved was obtained (for convenience R.Q. was assumed to be 1) and thus the total expected loss of organic carbon was calculated. This is compared with the measured loss of organic matter in Table 2. The calculated loss of carbon dioxide can more than account for the measured weight loss of the litter, and it is higher in each case probably because the calculations are based on a temperature of 10° C, whereas the tubes were below this temperature for part of the time. Also, the R.Q. may have been less than 1.

The litter in the tubes containing mull soil lost 22.37 to >50 % of the original organic matter, while in the tubes containing H-layer material the litter lost from 26.57 to 35.63 % of the original organic matter.

There seems to be some indication (Table 3) that in the tubes containing mull soil the litter from Bogle Crag Wood (mor) lost as much weight as did the litter from Meathop Wood (mull), showing that under these conditions they cannot have differed greatly in their availability to the organisms present. In the tubes containing H-layer material the litter from Meathop Wood lost slightly less than it did in the tubes of mull soil, and the Bogle Crag oak litter behaved similarly. It is not clear whether this

is due to a difference in organisms, a difference in the conditions of decomposition, or a combination of the two effects on the two soil types. It was also noticeable that the percentage loss in organic matter was not directly related to the degree of skeletonization of the litter by small animals (chiefly Collembola and enchytraeids with occasional mites) which appeared in most tubes because the soil and litter were not sterilized before use.

The dry weight losses obtained in this experiment using tubes of soil and litter were generally lower than those found by B o c o c k (1964) and H e - r i n g (1965) for litter exposed on the soil surface in the field in nylon mesh bags. The nylon mesh bag method has been criticized for various reasons (cf. W i e g e r t and E v a n s 1964). The method using litter/ soil mixtures in tubes as described above gives a much greater degree of control over the conditions of the experiment, and losses other than by decomposition can be avoided. This method is also sufficiently adaptable to be used in a wide range of studies involving soil and litter microorganisms and small animals.

ACKNOWLEDGEMENTS

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